

We claim:

- 1 1. Apparatus for deriving an analog output signal from an input signal
2 consisting of a first pulse-width modulated input signal representing positive values
3 and a second pulse-width modulated input signal representing negative values,
4 comprising:
5 an integrator circuit, connected to receive a first analog signal gated by the
6 first pulse-width modulated input signal and a second analog signal, of opposite
7 polarity to the first analog signal, gated by the second pulse-width modulated input
8 signal;
9 each of said first and second analog signals increasing in magnitude during
10 each pulse of the respective pulse-width modulated input signal.
- 1 2. The apparatus of claim 1 further comprising means for resetting said
2 integrator circuit, wherein operation of said resetting means also resets said first and
3 second analog signals to respective initial values.
- 1 3. The apparatus of claim 2 further comprising a sample-and-hold circuit
2 connected to an output of the integrator circuit.
- 1 4. The apparatus of claim 3 further comprising:
2 means for generating first and second constant signals of opposite polarity;
3 feedback means connected to an output of said integrator circuit for generating
4 a first feedback signal having the polarity of said first constant signal and a second
5 feedback signal having the polarity of said second constant signal, said feedback
6 signals being proportional to said output of said integrator circuit and having a
7 feedback gain;
8 means for adding said first constant signal to said first feedback signal to
9 provide said first analog signal; and
10 means for adding said second constant signal to said second feedback signal to
11 provide said second analog signal.

1 5. The apparatus of claim 4 further comprising:
2 means for adjusting the values of said first and second constant signals; and
3 means for adjusting said feedback gain independently of said adjustment of
4 said values of the constant signals.

1 6. The apparatus of claim 3 further comprising:
2 a first further integrator circuit connected to receive a first constant signal
3 gated by said first pulse-width modulated input signal;
4 a second further integrator circuit connected to receive a second constant
5 signal, of opposite polarity to said first constant signal, gated by said second pulse-
6 width modulated input signal;
7 first feed-forward means, connected to an output of said first further integrator
8 circuit, for deriving said first analog signal, and having a feed-forward gain;
9 second feed-forward means, connected to an output of said second further
10 integrator circuit, for deriving said second analog signal, and having a feed-forward
11 gain; and
12 adding means for adding an output signal of said integrator circuit, an output
13 signal of said first further integrator circuit and an output signal of said second further
14 integrator circuit;
15 wherein said resetting means is operative to reset said first and second further
16 integrator circuits.

1 7. The apparatus of claim 6 further comprising:
2 means for adjusting the values of said first and second constant signals; and
3 means for adjusting the feed-forward gains of said feed-forward means,
4 independently of said adjustment of the values of said constant signals.

1 8. A closed-loop control system comprising:
2 a local signal generator for generating a locally generated signal;
3 a comparator for comparing said locally generated signal with an input signal
4 to derive an error signal consisting of a first pulse-width modulated signal

5 representing positive error values and a second pulse-width modulated signal
6 representing negative error values; and
7 a pulse-width to analog converter connected to receive said pulse-width
8 modulated signals for deriving therefrom an analog control signal for said local signal
9 generator;
10 said pulse-width to analog converter being arranged to provide non-linear
11 conversion, whereby the ratio of the amplitude of the analog control signal to the
12 pulse width of the pulse-width modulated signals is greater for larger pulse widths
13 than for smaller pulse widths.

1 9. The closed-loop control system of claim 8 wherein the pulse-width to
2 analog converter comprises:
3 an integrator circuit, connected to receive a first analog signal gated by the
4 first pulse-width modulated input signal and a second analog signal, of opposite
5 polarity to the first analog signal, gated by the second pulse-width modulated input
6 signal;
7 each of said first and second analog signals increasing in magnitude during
8 each pulse of the respective pulse-width modulated input signal.

1 10. The closed-loop control system of claim 9 wherein said pulse-width to
2 analog converter further comprises:
3 means for resetting said integrator circuit, wherein operation of said resetting
4 means also resets said first and second analog signals to respective initial values.

1 11. The closed-loop control system of claim 10 wherein said pulse-width to
2 analog converter further comprises a sample-and-hold circuit connected to an output
3 of the integrator circuit.

1 12. The closed-loop control system of claim 11 wherein said pulse-width to
2 analog converter further comprises:
3 means for generating first and second constant signals of opposite polarity;
4 feedback means connected to an output of said integrator circuit for generating
5 a first feedback signal having the polarity of said first constant signal and a second

6 feedback signal having the polarity of said second constant signal, said feedback
7 signals being proportional to said output of said integrator circuit and having a
8 feedback gain;
9 means for adding said first constant signal to said first feedback signal to
10 provide said first analog signal; and
11 means for adding said second constant signal to said second feedback signal to
12 provide said second analog signal.

1 13. The closed-loop control system of claim 12 wherein said pulse-width to
2 analog converter further comprises:
3 means for adjusting the values of said first and second constant signals; and
4 means for adjusting said feedback gain independently of said adjustment of
5 said values of the constant signals.

1 14. The closed-loop control system of claim 11 wherein said pulse-width to
2 analog converter further comprises:
3 a first further integrator circuit connected to receive a first constant signal
4 gated by said first pulse-width modulated input signal;
5 a second further integrator circuit connected to receive a second constant
6 signal, of opposite polarity to said first constant signal, gated by said second pulse-
7 width modulated input signal;
8 first feed-forward means, connected to an output of said first further integrator
9 circuit, for deriving said first analog signal, and having a feed-forward gain;
10 second feed-forward means, connected to an output of said second further
11 integrator circuit, for deriving said second analog signal, and having a feed-forward
12 gain; and
13 adding means for adding an output signal of said integrator circuit, an output
14 signal of said first further integrator circuit and an output signal of said second further
15 integrator circuit;
16 wherein said resetting means is operative to reset said first and second further
17 integrator circuits.

- 1 15. The closed-loop control system of claim 14 wherein said pulse-width to
2 analog converter further comprises:
3 means for adjusting the values of said first and second constant signals; and
4 means for adjusting the feed-forward gains of said feed-forward means,
5 independently of said adjustment of the values of said constant signals.